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SURFACE VEHICLE STANDARD

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Automatic Transmission Intake Filter Test Procedure

1. Scope

This test procedure is intended to apply to hydraulic pump suction filters and strainers used in automotive automatic transmissions that include hydraulic power pumps. The various paragraphs of Section 5, "Test Procedures," include a variety of tests and alternative tests that are not applicable to all filters and applications, so the engineer must specify which tests are to be performed for a particular application. These test procedures are intended to evaluate filter functional performance characteristics only, durability is not evaluated under this standard.

Filter design requirements must be specified by the engineer on the filter assembly drawing, an applicable engineering specification, or they may be summarized on an application data sheet similar to that found in this recommended practice. See Figure 6, "Filter Assembly Application and Data Sheet."

Pressure circuit filters, both barrier and system contamination control types, are not covered under this standard. They are similar in design and construction to filters used in many hydraulic and lubricating applications.

1.1 Purpose

The purpose of this standard is to establish test methods to evaluate critical performance characteristics of automatic transmission intake (suction) filters. These units need ratings for flow capacity, temperature range, contaminant capacity, filter efficiency and other critical functional characteristics. These characteristics should be representative of a production feasible design and are to be applied to the filter assembly. Pressure side filters are covered by other existing test standards and practices.

Prior use of "nominal" and "absolute" filter ratings as applied to a filter's ability to capture particles of a given size have been deprecated. This standard predicates the use of "Filtration Ratios" (efficiency) or "Beta Ratios" to describe the capture effectiveness under reproducible test conditions using a known test contaminant.

1.2 Rationale

Not applicable.

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2. References

2.1 Applicable Publications

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest version of SAE publications shall apply.

2.1.1 SAE PUBLICATION

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE HS806—Oil Filter Test Procedure

2.1.2 ISO PUBLICATIONS

Available from ANSI, 25 West 43rd Street, New York, NY 10036-8002.

ISO 3722—Hydraulic fluid power—Fluid sample containers—Qualifying and controlling cleaning methods
ISO 3968—Hydraulic fluid power—Filters; evaluation of pressure drop versus flow
ISO 4021—Hydraulic fluid power—Particulate contamination analysis; Extraction of fluid samples from lines of operating systems
ISO 4405—Hydraulic fluid power—Fluid contamination; Determination of particulate contamination by gravimetric method
ISO 4406—Hydraulic fluid power—Method of coding level of contamination by solid particles
ISO 12103-1—Road vehicle—Test dust for filter evaluation
ISO 11943—Hydraulic fluid power—Fluid Contamination; Online liquid automatic particle counting systems—Method of calibration and validation
ISO 11171—Hydraulic fluid power—Calibration of automatic particle counters for liquids
ISO 16889—Hydraulic fluid power—Filters; Multi-pass method for evaluating filtration performance of filter elements

2.1.3 MILITARY PUBLICATION

Available from DODSSP, Subscripton Services Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

MIL-H-5606G—Fluid, Hydraulic – U.S. Military Specification: MIL-H-5606G

2.1.4 NFPA PUBLICATIONS

Available from the National Fluid Power Association, 3333 North Mayfair Road, Milwaukee, WI 53222-3219.

NFPA T3.1.64.1—Glossary of Terms for Hydraulic Fluid Power
NFPA T3.10.8.7—Hydraulic fluid power filter elements method for verifying flow fatigue characteristics
NFPA T3.10.14—Hydraulic fluid power filter determination of differential pressure-flow characteristics (Metric only)
NFPA T3.10.23—Multi-Pass Method for Evaluating Performance of Hydraulic Filters
NFPA T3.10.65.2—Filtration for Hydraulic Fluid Power Systems
NFPA T3.10.67.3—Glossary of Terms for Hydraulic Fluid Power Filters and Separators
NFPA T3.10.67.4—Graphic Symbols for Hydraulic Fluid Power Filters and Separators
ASTM MNL32—Manual on Test Sieving Methods
ASTM C778—ASTM graded sand specifications
USAS B93.2-1965—USA Standard Glossary of Terms for Fluid Power

2.2 Other Publications—General Information References

2.2.1 Larkin, Larry; Boast, Andrew; and Haggard, Dan, "SAE Publication AE-29," Chapter 14, Filtration and Contamination Control, publication pending 2004

2.2.2 Eleftherakis, John G. and Khalil, Abrahim, "Development of Laboratory Test Contaminant for Transmissions", SAE Paper No. 900561

2.2.3 Eleftherakis, John G. and Khalil, Abrahim, "Advance Filter Test Methods - Utilizing the Multi-Pass Test," TAPPI Press, 1993

2.2.4 Eleftherakis, John G. and Khalil, Abrahim, "Test Methods for Automotive Filtration," SAE Paper No. 930016

2.2.5 Hummel, Paul A., "Advancements in Automotive Transmission Sump Filtration," SAE Paper No. 960535

3. Definitions

Terms and Definitions: For definitions of terms not defined herein consult USA Standard Glossary of Terms for Fluid Power, USAS B93.2-1965; also identified as NFPA STD T3.1.64.1. See also NFPA Standard T3.10.67.4, Graphic Symbols for Hydraulic Fluid Power Filters and Separators, and NFPA Technical Manual T3.10.65.2, Filtration for Hydraulic Fluid Power Systems.

3.1 Filter

A device whose primary function is the retention by porous media of insoluble contaminants from a fluid.

3.2 Filter Types, Designs and Circuit Locations

Classification of filter assembly by application, circuit location, or usage.

3.2.1 BARRIER FILTER

A filter intended to capture particles, especially manufacturing debris, before they are carried into sensitive transmission components, e.g., control valves, bearings, etc. See 3.2.32, “Strainer.”

3.2.2 BLEED-OFF FILTER

A filter located in a return line between a flow control device and a reservoir.

3.2.3 BY-PASS FILTER

A filter, installed in an alternate flow path around the primary filter element, providing filtration when a preset differential pressure is reached in the primary filter element.

3.2.4 DISPOSABLE FILTER

A filter, which is intended to be discarded and replaced after one service cycle.

3.2.5 DUAL FILTER

A filter having two filter elements in parallel.

3.2.6 DUPLEX FILTER

An assembly of two filters with valving for selection of either or both filters.

3.2.7 EFFLUENT

The fluid leaving a component.

3.2.8 ELEMENT REMOVAL CLEARANCE

The minimum unobstructed distance required to remove the filter element from the housing or enclosure.

3.2.9 FILTERED BY-PASS

By-pass flow that is filtered through a filter element.

3.2.10 FULL FLOW FILTER

A filter which, under specified conditions, filters all the fluid flow in the hydraulic circuit in which it is installed.

3.2.11 IMPINGEMENT

The direct high velocity impact of the fluid flow upon or against any internal portion of the filter.

3.2.12 INFLUENT

The fluid entering a component.

3.2.13 IN-LINE FILTER

A filter in which the filter inlet, outlet, and filter housing axis are in a straight line.

3.2.14 L-TYPE FILTER

A filter in which the inlet and outlet port axis are at right angles, and the filter element is parallel or perpendicular to either port axis. This designation is sometimes applied to filters where the inlet and outlet ports are parallel but not collinear.

3.2.15 MANIFOLD FILTER

A filter containing multiple ports and integral related components which services more than one hydraulic circuit.

3.2.16 MODULAR FILTER

A filter which mounts to or within a manifold or subplate with flow passages at the interface.

3.2.17 NORMAL FLOW

The intended direction of flow through filter.

3.2.18 PARTIAL FLOW FILTER

A filter which filters a portion of the influent flow.

3.2.19 PILOT LINE FILTER

A filter located in a line conducting pilot fluid to a control device or devices.

3.2.20 PORT

An internal or external terminus of a passage in a component

3.2.21 PORT, INLET

A port that provides a passage for the influent.

3.2.22 PORT, DIFFERENTIAL PRESSURE

A port(s) that provides a passage to the upstream and downstream sides of a component.

3.2.23 PORT, OUTLET

A port that provides a passage for the effluent.

3.2.24 PORT-TO-PORT DIMENSION

The distance between inlet and outlet port measured from face to face or between centerlines.

3.2.25 PRESSURE LINE FILTER

A filter located in a pressurized line, usually the pump output, conveying the working fluid to a working device or devices.

3.2.26 PUMP INTAKE LINE FILTER

A filter located in a line conveying fluid to the pump inlet.

3.2.27 RESERVE FILTER

See 3.2.3, “By-Pass Filter.”

3.2.28 RESERVOIR FILTER

A filter installed in a reservoir in series with a suction or return line.

3.2.29 RETURN LINE FILTER

A filter located in a line conducting fluid from a working device to a reservoir.

3.2.30 REVERSE FLOW

Opposite to normal flow.

3.2.31 STARVATION

Insufficient filter effluent to allow proper functioning of downstream components.

3.2.32 STRAINER

A filter with a coarse filter element.

3.2.33 SUCTION FILTER

A pump intake line filter in which the fluid is below atmospheric pressure.

3.2.34 SUMP FILTER

A filter installed in a sump or reservoir, usually on the suction line leading to the pump, or on the return line.

3.2.35 SUPERCHARGE

A pump intake/filter outlet configuration in which fluid which is above atmospheric pressure, usually obtained by recirculating fluid from the pressure side of the pump, is injected through a nozzle at the filter outlet or pump intake thereby assisting or driving the main fluid stream, which is usually drawn from a reservoir, into the pump intake resulting in enhanced pump pressure and volume output.

3.2.36 T-Type Filter

A filter in which the inlet and outlet ports are located at one end of the filter with port axis in a straight line, and the filter element axis is perpendicular to this line, typically a spin-on filter.

3.2.37 Two-Stage Filter

A filter having two filter elements in series.

3.2.38 Wash or Self Cleaning

A filter designed so that a portion of the influent fluid flows parallel to the media surface on the unfiltered side of the media thereby continuously cleaning the influent surface by washing intercepted contaminant toward the edges of the media and out of the principal flow path.

3.2.39 Y or Multi-port Filter

A filter in which the inlet and outlet port axis and filter housing are in a Y configuration.

a. May refer to a dual inlet filter where one of the inlets may be a recirculation port.
b. May refer to a dual outlet filter where one of the outlets may feed the main hydraulic pump and the second outlet, usually smaller, may feed an auxiliary electric pressure sustaining pump used to maintain transmission engagement when the engine is not running.

3.3 Filter Components

The parts that make up a filter.

3.3.1 Baffle

A device to prevent direct flow impingement, or to guide the flow. Can be used inside the filter housing to prevent tunneling and channeling through the media by distributing the flow. When used on the outside of the filter, a baffle can prevent air ingestion during maneuvering or it can be used to guide spent fluid to the filter inlet.

3.3.2 Base

The foundation or support for the filter, which may also contain one or more ports.

3.3.3 By-Pass Valve

Used to allow fluid to by-pass the media, usually to give adequate flow under extreme cold conditions or where the filter is blocked by contamination. May be temperature or pressure regulated.

3.3.4 Cartridge

A filter element, usually replaceable.

3.3.5 CASE

A hollow part that provides a cavity or envelope for the filter element.

3.3.6 CENTER TUBE

The internal duct and filter media support.

3.3.7 COLD PATCH

A woven screen welded or otherwise placed over a by-pass opening in the filter media to improve fluid flow under extreme cold conditions.

3.3.8 CORE

See 3.3.6, "Center Tube."

3.3.9 CORRUGATIONS

See 3.3.23, "Pleats."

3.3.10 COVER

A closure, which provides access to the filter element.

3.3.11 CREST

The outer fold of a pleat.

3.3.12 END SEAL

The bond between the end cap and the filter medium often obtained by potting the element. Also a sealing methodology where the filter media seals against the end cap by axial contact pressure.

3.3.13 ELEMENT

The porous device which performs the actual process of filtration

3.3.14 EXTERNAL SUPPORT

A permeable structural enclosure, which imparts rigidity to a filter element and usually protects the filter medium.

3.3.15 FEET

Risers on the bottom of the filter to keep the filter housing off the sump pan and allow fluid flow to the filter inlet.

3.3.16 GROOVING

Shallow ridges in the filter medium perpendicular to the roots of the pleats.

3.3.17 HOUSING

A ported enclosure which directs the flow of fluid through the filter element.

3.3.18 INTERNAL SUPPORT

A permeable structural part which imparts rigidity to a filter element, and is primarily used to prevent filter element collapse. See 3.3.31, “Support.”

3.3.19 MEDIA

The porous layer of material that performs the actual particle interception, i.e., does the filtering.

3.3.20 MEDIUM

See 3.3.19 “Media.”

3.3.21 NOZZLE

A shaped port directed into the pump intake so as to supercharge the fluid entering the pump intake.

3.3.22 OUTER WRAPPER

A permeable enclosure, which protects the filter medium.

3.3.23 PLEATS

A series of folds in the filter medium usually of uniform height and spacing, used to increase filter media area.

3.3.24 PRESSURE RELIEF VALVE

A valve installed on the filter housing to prevent the pressure from building up inside the filter, usually from air trapped inside the valve body and hydraulic tubing which is compressed when the transmission is first engaged and which enters the filter though a by-pass recirculation route or by reverse flow through the pump thereby causing the filter to burst. See also 3.3.3 “By-Pass Valve.”

3.3.25 RESERVOIR

May be internal or external to maintain a supply of fluid thereby helping to prevent air ingestion and resulting loss of pump prime especially during maneuvering.

3.3.26 ROOT

The inner fold of a pleat.

3.3.27 SEAL

A component or feature used to prevent cross media leakage or hydraulic short circuit thereby insuring leak free separation of hydraulic circuits.

3.3.28 SHELL

See 3.3.5, "Case."

3.3.29 SIDE SEAL

The longitudinal seam of the filter medium in a filter element.

3.3.30 STAND-OFF

A projection integrated into the filter element or housing to maintain proper spacing between filters elements, or adjacent components.

3.3.31 SUPPORT

Part or feature used to provide support to the filter media so as to prevent collapse. May also be configured to act as a baffle to direct flow or prevent media damage from high velocity flow impingement.

3.4 Filter Accessories

Auxiliary devices incorporated into a filter to enhance its usefulness.

3.4.1 MAGNET OR MAGNETIC PLUG

A magnet which attracts and holds ferromagnetic particles. See also 3.5.10, "Magnetic Element."

3.4.2 SWITCH, FLOW

An electric switch operated by fluid flow.

3.4.3 SWITCH, PRESSURE

An electric switch operated by fluid pressure.

3.4.4 SWITCH, DIFFERENTIAL PRESSURE

An electric switch operated by a difference in pressure.

3.4.5 VALVE

A device, which controls fluid flow, direction, pressure, or flow rate.

3.4.6 VALVE, BY-PASS

A valve whose primary function is to provide an alternate flow path.

3.4.7 VALVE, CHECK

A valve that provides directional control by permitting flow of fluid in only one direction.

3.4.8 VALVE, FLOW CONTROL

A valve whose primary function is to control flow rate.

3.4.9 VALVE, RELIEF, DIFFERENTIAL PRESSURE

(a) A valve whose primary function is to limit filter element differential pressure by opening a parallel unfiltered fluid path around the media;
(b) a valve installed in the filter housing whose function is to prevent pressurization of the filter housing from back flow or other pressure transient that might cause the housing to burst.

3.4.10 VALVE, INERTIA, SHUTTLE, INLET

A valve that moves in response to the forces associated with maneuvering, switching the fluid intake between two possible inlet openings so the inlet used is always submerged in fluid thereby preventing air ingestion.

3.4.11 VALVE, THERMOSTATIC

A valve that operates in response to a change in temperature, usually installed in a by-pass circuit to open and provide enhanced flow under cold conditions where the increased viscosity of the fluid prevents the fluid from moving readily through the filter media.

3.5 Filter Element Types

Classification of filter elements by construction, application or method of filtration

3.5.1 BI-DIRECTIONAL ELEMENT

A filter element designed for flow in both directions.

3.5.2 CAKED ELEMENT

An accumulation of contamination that partially blocks off the filter media. May also be a layer of material intentionally loaded on the filter media before the filter is placed in service to increase efficiency or to create a depth media or a media with a special property or characteristic.

3.5.3 CLEANABLE ELEMENT

A filter element which when loaded can be restored by a suitable cleaning process to an acceptable percentage of its original dirt holding capacity.

3.5.4 CORRUGATED ELEMENT

See 3.5.14, "Pleated Element."

3.5.5 DISPOSABLE ELEMENT

A filter element, usually enclosed in a housing, which is intended to be discarded and replaced after one service cycle.

3.5.6 EXTENDED AREA ELEMENT

A filter element whose medium is pleated or otherwise formed to obtain more effective area within a given dimensional envelope. See also 3.8.14, "Effective Area."

3.5.7 FULL SYSTEM DIFFERENTIAL PRESSURE ELEMENT

A filter element which will withstand a differential pressure at least equal to the maximum system operating pressure without structural or filter medium failure.

3.5.8 INSIDE-OUT FLOW ELEMENT

A filter element designed for normal flow outward from and perpendicular to the axis of the filter element.

3.5.9 INTAKE FILTER ELEMENT

A filter element, which is installed in the pump intake line.

3.5.10 MAGNETIC ELEMENT

A filter component which may be incorporated inside or outside the media support structure to attract and hold ferromagnetic particles.

3.5.11 MODULAR ELEMENT

A filter element, which has no separate housing of its own, but utilizes a housing incorporated into the equipment which it services. The housing may also include a suitable closure for the filter cavity.

3.5.12 OUTSIDE-IN FLOW ELEMENT

A filter element designed for normal flow perpendicular and toward the axis of the filter element.

3.5.13 PLAIN ELEMENT

A filter element whose medium is not pleated or otherwise extended and has the geometric form of a cylinder, cone, disc, plate, etc.

3.5.14 PLEATED ELEMENT

A filter element whose medium consists of a series of uniform folds and has the geometric form of a cylinder, cone, disc, plate, etc.

3.5.15 PLUG-IN ELEMENT

See 3.5.11, “Modular Element.”

3.5.16 PRIMARY ELEMENT

The first filter element in a series, or the main filter element of a filtered by-pass filter assembly.

3.5.17 RESERVE ELEMENT

A standby filter element.

3.5.18 RESERVOIR ELEMENT

A filter element in a reservoir installed in series with a suction or return line. May be in an enclosure or exposed inside the reservoir.

3.5.19 SECONDARY ELEMENT

The second of two filter elements in series.

3.5.20 SELF CLEANING ELEMENT

A filter element designed to be cleaned without removing it from the filter assembly.

3.5.21 SERIAL ELEMENT OR FILTRATION MEDIA

Two or more media layers of different pore size used to capture and retain successively finer particles.

3.5.22 STRAINER

A coarse filter element.

3.5.23 SUCTION FILTER ELEMENT

See 3.5.9, “Intake Filter Element.”

3.5.24 SUMP FILTER ELEMENT

See 3.5.18, “Reservoir Element.”

3.5.25 SURFACE ELEMENT

A filter element that uses a woven or punched single layer filter element material with uniform hole sizes. The particle capture and retention mechanism is by straining or sieving of particles larger than the nominal hole size.

3.5.26 THROW-AWAY ELEMENT

See 3.5.5, “Disposable Element.”

3.5.27 TWO-STAGE ELEMENT

A filter element assembly composed of two filter elements or media in series.

3.5.28 WASHED ELEMENT

A filter element in which a larger unfiltered portion of the fluid flowing parallel to the filter element axis is utilized to continuously clean the influent surface, which filters the lesser flow.

3.6 Filter Element Media

The porous materials, which performs the actual process of filtration.

3.6.1 ABSORBENT MEDIA

A filter medium that holds contaminant by mechanical means.

3.6.2 ABSORPTIVE MEDIA

See 3.6.1 “Absorbent Media.”

3.6.3 ADSORBENT MEDIA

A filter medium primarily intended to hold soluble and insoluble contaminants on its surface by molecular adhesion.

3.6.4 ADSORPTIVE MEDIA

See 3.6.3 “Adsorbent Media.”

3.6.5 BINDER

Material applied to media during process, usually by dipping or spraying, to prevent media migration or shedding in use.

3.6.6 COMBINATION MEDIA

A filter medium composed of two or more types, grades, or arrangements of filter media to provide properties, which are not available in a single filter medium.

3.6.7 COMPOSITE MEDIA

See 3.6.6, "Combination Media."

3.6.8 DEPTH MEDIA

A thick media layer that uses adsorption and entanglement as the particle capture and retention mechanism. See also 3.5.21, "Serial Element."

3.6.9 DEPOSITED MEDIA

A media which primarily retains contaminant on its surface or within tortuous passages. See also 3.5.2, "Caked Element."

3.6.10 EDGE MEDIA

A filter media whose passages are formed by the adjacent surfaces of stacked discs, edge-wound ribbons, or single-layer filaments.

3.6.11 MESH

The count or number of mesh opening per linear distance in a woven filter cloth, e.g., "250 Mesh" indicates 250 openings per inch. Usually specified in inches, but may be specified in millimeters.

3.6.12 NON-WOVEN MEDIA

A filter media composed of a random mat of fibers.

3.6.13 PRECOATED MEDIA

A media that has been treated with a coating or a deposit to impart special characteristics to the media whereby the media's ability to collect and hold contamination is enhanced; a coating that has an affinity for a particular type of particle to attract and hold a specific type of contamination. See also 3.5.2, "Caked Element."

3.6.14 SINTERED MEDIA

A metallic or non-metallic filter medium processed to cause diffusion bonds at all contacting points.

3.6.15 SURFACE MEDIA

A filter media, which primarily retains contaminant on the influent face.

3.6.16 WOUND MEDIA

A filter medium comprised of two or more layers of helical wraps of continuous strands or filament in a predetermined pattern.

3.6.17 WOVEN MEDIA

A filter medium made from strands of fiber, thread, or wire repetitiously interlaced into a cloth on a loom.

3.7 Filter Element Operating Mode Conditions

Conditions that may occur during operation of the filter throughout its useful life.

3.7.1 ARTIFICIALLY LOADED

A filter element that is loaded with a controlled laboratory test contaminant.

3.7.2 BRIDGING

A condition of filter element loading in which contaminant spans the space between adjacent sections of a filter element thus blocking a portion of the useful filtration area.

3.7.3 BURST

An outward structural failure of the filter element caused by excessive differential pressure.

3.7.4 CAKING

An accretion of contaminant or particulate that can result in reduced flow and at the same time increased filtration efficiency.

3.7.5 CLEAN

A new or properly cleaned filter element.

3.7.6 COLLAPSED

An inward structural failure of the filter element caused by excessive differential pressure.

3.7.7 CHANNELING

See 3.7.16 "Tunneling"

3.7.8 CONTAMINATED

A filter element which contains foreign particles resulting from handling, storage, and fabrication.

3.7.9 DIRTY

A used filter element that is partially or completely loaded.

3.7.10 FATIGUED

A structural failure of the filter medium due to flexing caused by cyclic differential pressure.

3.7.11 LOADED

A filter element that has collected a sufficient quantity of insoluble contaminants such that it can no longer pass rated flow without excessive differential pressure.

3.7.12 PINCHED PLEAT

A pleat closed off by excessive differential pressure or crowding, thus reducing the effective area of the filter element.

3.7.13 PLUGGED

See 3.7.11, "Loaded."

3.7.14 RUPTURED

Any tear or split in the filter medium.

3.7.15 SERVICE LOADED

A filter element, which is loaded from actual use.

3.7.16 TUNNELING

Breakdown of the filter media caused by focused fluid flow; a hole or tear caused by high energy (kinetic or thermal) fluid stream.

3.8 Filter Performance

Those factors, which describe the functions and attributes of a filter or filter element.

3.8.1 ABSOLUTE FILTRATION RATING

Historically, the diameter of the largest hard spherical particle that will pass though a filter under specified test conditions. Due to lack of reproducible test methods, this rating is now deprecated.

3.8.2 BETA RATIO

A value calculated by measuring particle size concentration up and downstream of the filter assembly, used as an indicator of filter efficiency.

$$\beta_x = \frac{\text{Number of particles larger than X upstream}}{\text{Number of particles larger than X downstream}} \qquad \text{(Eq. 1)}$$

3.8.3 BUBBLE POINT

The differential gas pressure at which the first steady stream of gas bubbles are emitted from a wetted filter element under specified test conditions; a means to indicate the pore size.

3.8.4 BURST PRESSURE

The pressure which causes rupture. Also, the inside-out differential pressure that causes outward structural or filter medium failure of a filter element.

3.8.5 BURST PRESSURE RATING

The maximum specified inside-out differential pressure which can be applied to a filter element without outward structural or filter medium failure.

3.8.6 CLEANABILITY

The ability of a cleanable filter element to withstand repeated field cleanings and retain adequate dirt capacity and service life.

3.8.7 COLLAPSE PRESSURE

The outside-in differential pressure that causes structural or filter medium failure of a filter element.

3.8.8 COLLAPSE PRESSURE RATING

The maximum specified outside-in differential pressure which can be applied to a filter element without inward structural or filter medium failure.

3.8.9 CONTAMINANT CAPACITY

See 3.8.12, “Injected Capacity,” and 3.8.32, “Retained Capacity.”

3.8.10 CONTAMINANT MIGRATION

Contaminant, previously captured by the media, that has passed through the media, been released, and has proceeded downstream.

3.8.11 DIFFERENTIAL PRESSURE

The difference in pressure between any two points of a system or a component.

3.8.12 INJECTED CAPACITY

The weight of a specified artificial contaminant, which must be added to the influent to produce a given differential pressure across a filter at specified conditions.

3.8.13 DUST CAPACITY

See 3.8.12, "Injected Capacity."

3.8.14 EFFECTIVE AREA

The total area of the porous medium in a filter element exposed to flow. Note that the flow through the media is usually not the same everywhere because of the proximity and configuration of the housing, flow distribution channels, media supports, and baffles and, as a result, some areas of the media may be less effective than other areas.

3.8.15 EFFICIENCY

The ability, expressed as a percent, of a filter to remove a specified contaminant at a given contaminant concentration under specified test conditions.

3.8.16 END LOAD

The axial force applied to the end of a filter element which may cause permanent deformation or seal failure.

3.8.17 END LOAD RATING

The maximum specified axial force which can be applied to a filter element without permanent deformation or seal failure.

3.8.18 FILTRATION RATIO

See 3.8.2, "Beta Ratio."

3.8.19 FLOW FATIGUE

A structural failure of the filter medium due to flexing caused by cyclic flow.

3.8.20 LARGEST PARTICLE PASSED

See 3.8.1, "Absolute Filtration Rating."

3.8.21 MEDIA MIGRATION

Contaminant, in the form of filter media that has separated from its substrate, or manufacturing debris left in the filter assembly, that is released and proceeds downstream.

3.8.22 NOMINAL FILTRATION RATING

An arbitrary micron value listed by a filter manufacturer. Due to lack of reproducibility this rating is deprecated. See 3.8.1, "Absolute Filtration Rating," 3.8.15, "Efficiency," and 3.8.2, "Beta Ratio."

3.8.23 OPEN AREA RATIO

The ratio of pore area to total area of a filter medium expressed as a ratio, fraction, or percent. This is applicable to woven or perforated fabrics.

3.8.24 PERCENT OPEN AREA

The pore area of a filter medium expressed as a percent of total area. This is applicable to woven or perforated fabrics. See also 3.8.23, "Open Area Ratio."

3.8.25 PERMEABILITY

The relationship of flow per unit area to differential pressure across a filter medium.

3.8.26 PORE SIZE DISTRIBUTION

The ratio of the number of holes of a given size to the total number of holes per unit area expressed as a percent and as a function of hole size.

3.8.27 POROSITY

The ratio of pore volume to total volume of a filter medium expressed as a percent. Applicable to depth media such as sintered or non-woven fabric.

3.8.28 PRESSURE DROP

See 3.8.11, "Differential Pressure."

3.8.29 PRESSURE FATIGUE

A structural failure of the filter medium due to flexing caused by cyclic differential pressure.

3.8.30 PROOF PRESSURE

The non-destructive test pressure in excess of the maximum rated operating pressure, which causes no permanent deformation, excessive external leakage, or other malfunction.

3.8.31 RESIDUAL DIRT CAPACITY

The dirt capacity remaining in a service loaded filter element after use, but before cleaning, measured under the same conditions as the dirt capacity of a new filter element.

3.8.32 RETAINED CAPACITY

The mass of particulate contaminant effectively retained by the filter element when terminal pressure is reached. This is an empirical value that can be calculated from test data by subtracting the weight of contaminant remaining in the test stand at the end of test from the Injected Dirt Capacity, see 3.8.12, "Injected Capacity". The Retained Capacity may be used as an indication of relative service life.

3.8.33 SLOUGHING OFF

The release of contaminant from the upstream surface of a filter element to the upstream side of the filter enclosure.

3.8.34 TERMINAL PRESSURE

That differential pressure required to produce a specified flow rate at a specified viscosity when the filter has reached its specified dirt capacity.

3.8.35 TORTUOSITY

The ratio of the average effective flow path length to minimum theoretical flow path length (thickness) of a filter medium.

3.8.36 TOTAL AREA

The entire area of a porous media, whether effective or not, in a filter element.

3.8.37 UNLOADING

The release of contaminant that was initially captured by the filter media.

3.8.38 VOID FRACTION

See 3.8.27, "Porosity."

3.9 Separator

A device whose primary function is to isolate contaminants by physical properties other than size.

3.9.1 ADSORBENT

A separator that retains certain soluble and insoluble contaminants by molecular adhesion.

3.9.2 CENTRIFUGAL

A separator that removes non-miscible fluid and solid contaminants that have a different specific gravity than the fluid being purified by accelerating the fluid in a circular path and using the radial acceleration component to isolate these contaminants.

3.9.3 COALESCING

A separator that divides a mixture or emulsion of two immiscible liquids using the interfacial tension between the two liquids and the difference in wetting of the two liquids on a particular porous medium.

3.9.4 ELECTROSTATIC

A separator that removes contaminant from dielectric fluids by applying an electrical charge to the contaminant which is then attracted to a collection device of different electrical charge.

3.9.5 MAGNETIC

A separator that uses a magnetic field to attract and hold ferromagnetic particles. See 3.5.10, “Magnetic Element.”

3.9.6 TWO PHASE

A separator that is capable of dividing a liquid and gas mixture.

3.9.7 VACUUM

A separator that utilizes sub-atmospheric pressure to remove certain gases and liquids from another liquid because of their difference in vapor pressure.

4. Tests and Equipment

4.1 Hydraulic Test Circuits

The circuits illustrated in Figures 1A and 1B are based on approved practice outlined in ISO 16889 to test filters operating at pressures above atmospheric - “Pressure Mode.” These circuits are suitable for completing all tests in this recommended practice except “Pressure Drop (Flow Rating)” at extreme cold temperatures, generally taken to mean temperatures below –25 °C. These circuits are preferred for completing 5.1.1 “Steady State Multi-Pass Efficiency” (Figure 1A) and 5.1.2 “Pulsed Flow Efficiency” (Figure 1B) tests because they permit direct measurement of particle size concentration and distribution by automatic particle counters. Figures 2A and 2B illustrate circuits appropriate when test filter flow is compelled via atmospheric pressure – generally known as “Suction Mode.” These circuits are likewise suitable for evaluating “Steady State Multi-Pass Efficiency” (Figure 2A) and “Pulsed Flow Efficiency”

(Figure 2B); however, this alternate method infers influent contaminant concentration via reservoir sampling in lieu of upstream and downstream particle counting. Both methods, "Pressure Mode" or "Suction Mode," require validation in accordance with procedures outlined below (see 4.4.7.3 "Validation"). For either method, the Test Stand supply must be capable of producing sufficient flow, controlling temperature and pressure, and maintaining the test contamination in suspension throughout the test.

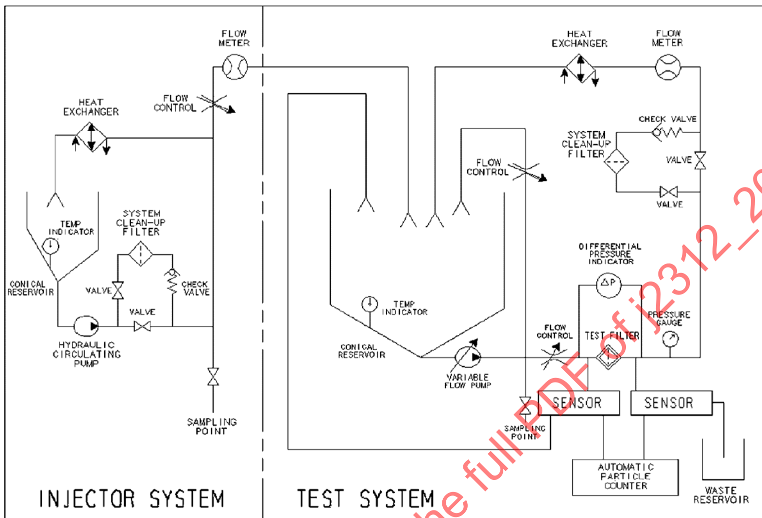

FIGURE 1A—TYPICAL INTAKE FILTER TEST CIRCUIT: PRESSURE MODE, STEADY STATE MULTI-PASS TEST

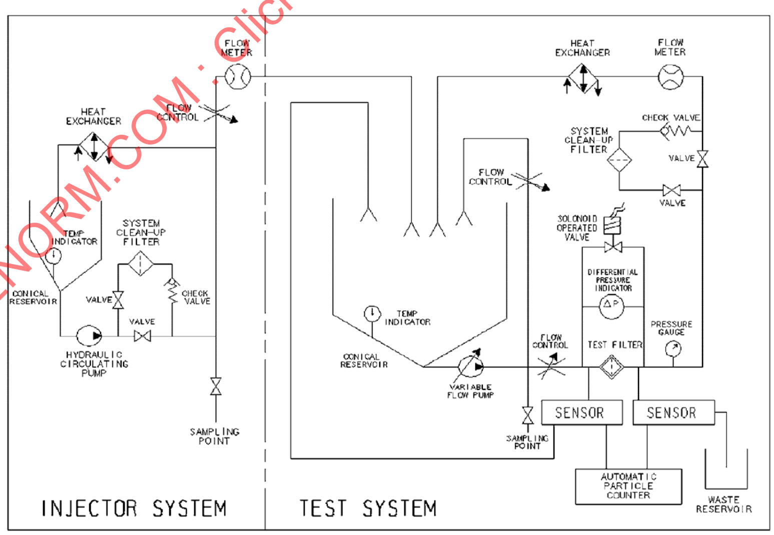

FIGURE 1B—TYPICAL INTAKE FILTER TEST CIRCUIT: PRESSURE MODE, PULSED FLOW EFFICIENCY TEST

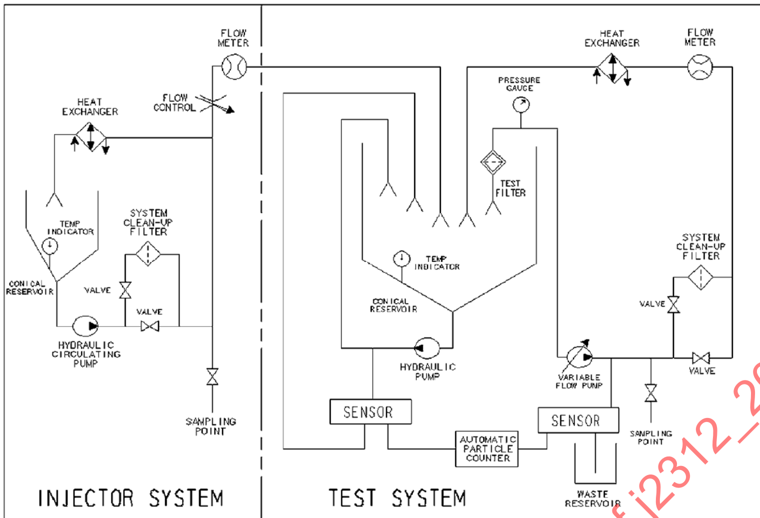

FIGURE 2A—TYPICAL INTAKE FILTER TEST CIRCUIT: SUCTION MODE,
STEADY STATE MULTI-PASS TEST

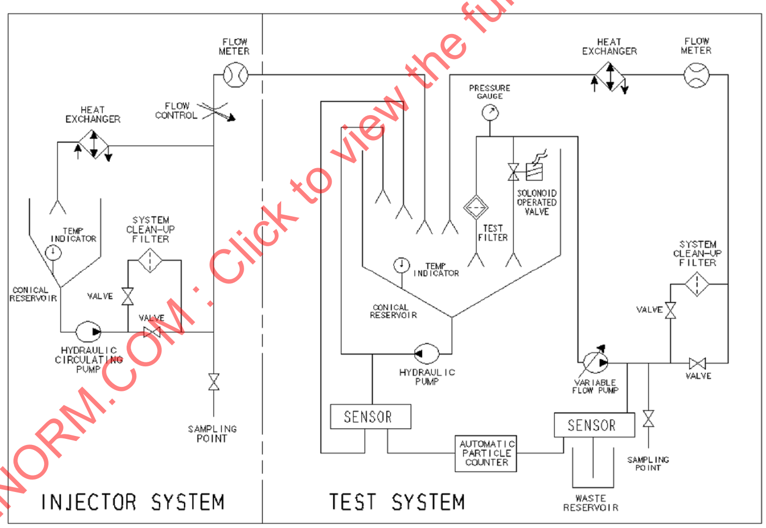

FIGURE 2B—TYPICAL INTAKE FILTER TEST CIRCUIT: SUCTION MODE,
PULSED FLOW EFFICIENCY TEST

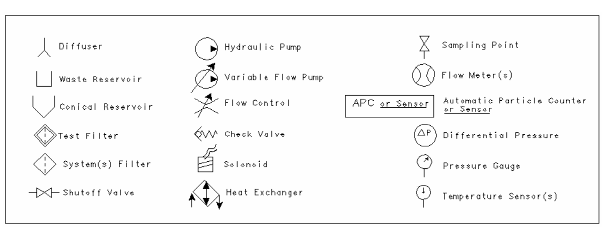

FIGURE 3—SCHEMATIC LEGEND

NOTE—All equipment, test stand circuits, measuring devices and data acquisition equipment must be certified in accordance with ISO 16889, ISO 11943 and ISO 11171. The Hydraulic Schematic Legend, Figure 3, illustrated previously, is applicable to all schematics found in this document.

4.2 Test Fluid

4.2.1 Filter Pressure Drop Test

Shall be conducted using the transmission manufacturer's specified fluid, i.e., the fluid intended to be used for "Factory Fill" for the subject application. Fluid cleanliness level and the test method for fluid cleanliness verification must be specified.

4.2.2 Filter Contaminant Rating Tests

Shall be conducted with MIL H 5606 G Hydraulic Fluid to establish standard rating for test dust capacity, media migration and filter efficiency. Alternative fluids meeting the specifications of ISO 16889, Paragraph 6.7 "…petroleum base test fluid…" may also be used. Automatic Transmission Fluid (ATF) is not appropriate for use in this test.

4.3 Test Contaminants

Test contaminants may be divided into four major categories that include test dust, glass beads, metal powders and special test contaminants that have a documented formulation. Based on the specified filtration test (e.g., efficiency, capacity, etc.) and the specifications to which these tests are being conducted, one or more categories of test contaminants may be utilized in the following Filter Assembly Multi-Pass test procedures. A description of the test contaminants and their test use follows. The Intake Filter Assembly Test Report, Steady State Multi-Pass Efficiency Test (see Figure 4) must indicate the formulation, identification, originating laboratory, governing standard, particle size distribution, and material content.

4.3.1 Test Dust

In accordance with ISO 12103-1, test dusts are usually manufactured from Arizona desert sand which is a naturally occurring contaminant consisting primarily of silicon dioxide and other compounds. These test dusts are abrasive in nature and are commonly found as contaminants in motor vehicle power trains. Arizona desert sand has a density of approximately 2,650 kg/m^3. Generally, Arizona Test Dust is used in multi-pass filtration efficiency tests and capacity tests. Arizona Test Dusts are classified into four standard grades described in Table 1, "Test Dust Classification."

NOTE—Paragraph 4.3.1.1 describes how to make dry test dust stock from bulk material. This stock will be used (added) to the hydraulic test system to achieve particle concentrations found in Table 3A and 3B, "Acceptable Cumulative Particle Counts per 100 milliliter."

TABLE 1—TEST DUST CLASSIFICATION

ISO Designation	Description	Approx. Bulk Density
ISO 12103-1 A1 Ultrafine	0 – 20 Micron Test Dust	500 kg/m^3
ISO 12103-1 A2 Fine	1 – 120 Micron Test Dust	900 kg/m^3
ISO12103-1 A3 Medium	2 – 120 Micron Test Dust	1025 kg/m^3
ISO 12103-1 A4 Coarse	5 – 200 Micron Test Dust	1200 kg/m^3

4.3.1.1 For pulsed flow efficiency tests, the preferred test contaminant is Coarse Sieved Grade (140 to 300 microns) graded silica grains, sieved and calibrated in accordance with ASTM C 778, "Graded Sand Specifications." Preparation of the mix is as follows: For Use C778 graded silica grains. The test contaminant consists of two parts, each contributing to the final mix, 50% by weight. Pass the stock material through a 514-micron screen, then through a 250-micron screen. All material captured on the 250-micron screen is to be used for part 1. Material that has passed through the 250-micron screen should then be passed through a 150-micron screen. All material remaining on the 150-micron screen is to be used for part 2.

4.3.1.2 For Multi-Pass Efficiency Tests, the preferred test contaminant is "Medium Sieved Grade" (20-100 micron) made from ISO 12103-1 A4. Prepare this material by sieving ISO 12103-1 A4, "Coarse" test dust with a 53 micron screen in accordance with ASTM Procedure ASTM MNL32, "Manual on Test Sieving Methods." All material remaining on the 53-micron screen after first passing through a 100-micron sieve is to be used as the "Medium Sieved Grade" test contaminant.

Test Lab	Test Date	Tech

Filter Assembly Part No.	Rev Level & Date Test ID No

Test Conditions

Test Fluid ______	Supplier ______	Test Temperature ________
Test Contaminant Type________	Supplier ________	Certification
Test System – Main Flow Rate ________ Base Upstream Concentration Level *(See Table 2 "Test Condition Values" for specification)*	Initial Volume __________	Final Volume ______

Injection System

Injection System Parameters	Initial	Final	Average	Injection Parameters
System Volume (l)			Injection Flow (l/min)	_________ ______
Concentration (mg/l)			Concentration (mg/l)	_________ ______

Counting System	Counter and Sensor Ref	Flow Rate (l/min)	Dilution Ratio
Upstream			
Downstream			
Counter Calibration	Method	Date	

FIGURE 4A—TYPICAL INTAKE FILTER ASSEMBLY TEST REPORT STEADY-STATE MULTI-PASS EFFICIENCY TEST

Differential Pressure							
Filter Assembly-Clean				Filter Assembly - Terminal			
Differential Pressure versus Contaminant added							
Time Interval	Test Time (elapsed time)	Assy Diff Press	Injected Mass	Time Interval	Test Time (elapsed time)	Assy Diff Press	Injected Mass
10%				60%			
20%				70%			
30%				80%			
40%				90%			
50%				100%			
Retained Capacity							
Contaminant Mass Injected		______ mg		Contaminant Mass Retained		___mg	
Upstream Gravimetric Level @ 80%		______ mg/l					

FIGURE 4B—INTAKE FILTER ASSEMBLY TEST REPORT STEADY-STATE MULTI-PASS EFFICIENCY TEST (CONTINUED)

Test Time Interval		> 20	Beta	>40	Beta	>60	Beta	>80	Beta	> 100	Beta	>120	Beta	>140	Beta	> 160	Beta
Initial Upstream																	
@ 10%	Upstream																
	Downstream																
@ 20%	Upstream																
	Downstream																
@ 30%	Upstream																
	Downstream																
@ 40%	Upstream																
	Downstream																
@ 50%	Upstream																
	Downstream																
@ 60%	Upstream																
	Downstream																
@ 70%	Upstream																
	Downstream																
@ 80%	Upstream																
	Downstream																
@ 90%	Upstream																
	Downstream																
@ 100%	Upstream																
	Downstream																

FIGURE 4C—INTAKE FILTER ASSEMBLY TEST REPORT STEADY-STATE MULTI-PASS EFFICIENCY TEST (CONTINUED)

4.3.2 GLASS BEADS

Micronic glass beads are used primarily in single pass efficiency tests to improve repeatability when gravimetric analysis is required. The beads are generally round, smooth spheres, and as such, are considered by most filtration experts to be non-representative of contaminants found in actual applications. For these and other reasons, glass beads require special handling (see SAE HS 806). Glass beads are readily available in sizes from 10 microns to 150 microns. However, the following sizes are most frequently used:

4.3.2.1 10 to 20- Micron Glass Beads

Used for high efficiency pressure side filters, such as used in hydrostatic transmission.

4.3.2.2 10 to 70- Micron Glass Beads

Used for general pressure side filters, such as lubrication filters.

4.3.2.3 10 to 150- Micron Glass Beads

Used for suction filters, coarse pressure filters such as barrier screens, and pump intake filters.

4.3.3 METAL POWDERS

4.3.3.1 Synthetic Formulations

Synthetic formulations constituted with a particle size distribution and material content as specified by the design engineer and accompanied by laboratory certified distribution may be used in tests of filter assemblies including those that have an auxiliary means of particle capture and retention.

4.3.3.2 Iron Based Powder Metal (PM) Base Stock

For special tests that require metal powders of known particle size distribution and chemical content to test auxiliary means of particle capture such as magnets, specially prepared contaminants may be used. Laboratory certification of particle size distribution and material content shall be obtained.

4.3.4 OTHER CONTAMINANTS

Other contaminants not specified herein may be used for testing under this recommended practice. However, all test results must be accompanied by an “Intake Filter Assembly Test Report, Steady State Multi-Pass Test” (see Figure 4), and/or an “Intake Filter Assembly Test Report, Pulsed Flow Test” (see Figure 5) indicating the formulation identification, originating laboratory, governing standard, particle size distribution, and material content.

4.4 Test Equipment

Suitable test circuits that have proved successful are illustrated in Figure 1A and 2A. Related equipment not illustrated which may be useful or necessary is described below.

4.4.1 TIMER

Use a suitable timer for measuring time.

4.4.2 PARTICLE COUNTER

Use an automatic particle counter(s) calibrated in accordance with ISO 11171.

4.4.3 TEST CONTAMINANTS

Use the test contaminant specified by the test requester. If different from those test contaminants listed in 4.3 "Test Contaminants," the requester must provide full definition to include particle size concentration and distribution. Dry the contaminant in an oven at 110 °C for not less than 1 hour for quantities less than 200 gms and for use in the test system. Mix in the test fluid. Mechanically agitate then disperse ultrasonically with a power density of 3000 Watts/m^3 to 10 000 Watts/m^3.

4.4.4 PARTICLE COUNTING

Use an online particle counter (see 4.4.2), with a dilution system if necessary, that has been validated in accordance with ISO 11943.

4.4.5 SAMPLE BOTTLES

Bottle samples should be used for gravimetric analysis only. Online particle counting is the preferred method. However, for gravimetric analysis, use sample bottles containing less than 20 particles per milliliter of bottle volume greater than 6 microns as qualified per ISO 3722, "Hydraulic Fluid Power – Fluid Sample Containers – Qualifying and Controlling Cleaning Methods."

Test Lab	Test	Date	Tech

Filter Assembly Part No.	Rev Level & Date Test ID

Test Conditions

Test Fluid	Supplier	Test Temperature
Test Contaminant Type	Supplier	Certification
Test System - Main Flow Rate Base Upstream Concentration Level *(See Table 2 "Test Condition Values" for specification)*	Initial Volume	Final Volume

Injection System

Batch No.	1	2	3	4	5	6	7	8
Batch Weight (mg)								
Batch Sieve Date								

Test Results

Differential Pressure

Filter Assembly-Clean	Filter Assembly - Terminal

Differential Pressure versus Contaminant added

Time Interval	Test Time (elapsed time)	Assy Diff Press	Injected Mass	Time Interval	Test Time (elapsed time)	Assy Diff Press	Injected Mass
10%				60%			
20%				70%			
30%				80%			
40%				90%			
50%				100%			

Retained Capacity

Contaminant Mass Injected ______ mg

Contaminant Mass Retained ___mg

Upstream Gravimetric Level @ 80% ______ mg/l

FIGURE 5A—TYPICAL INTAKE FILTER ASSEMBLY TEST REPORT - PULSED FLOW TEST

Particle Counts (particle per ml) and Beta Ratio

Test ID No. ____________

Test Time Interval		> 140	Beta	>160	Beta	>180	Beta	>200	Beta	> 220	Beta	>240	Beta	>260	Beta	> 280	Beta
Initial Upstream																	
@ 10%	Upstream																
	Downstream																
@ 20%	Upstream																
	Downstream																
@ 30%	Upstream																
	Downstream																
@ 40%	Upstream																
	Downstream																
@ 50%	Upstream																
	Downstream																
@ 60%	Upstream																
	Downstream																
@ 70%	Upstream																
	Downstream																
@ 80%	Upstream																
	Downstream																
@ 90%	Upstream																
	Downstream																
@ 100%	Upstream																
	Downstream																

FIGURE 5B—INTAKE FILTER ASSEMBLY TEST REPORT - PULSED FLOW TEST (CONTINUED)

TABLE 2—TEST CONDITION VALUES

Test Conditions[1] Base upstream gravimetric, mg/l[1][2]	Condition 1[3] For small or high efficiency filters. 10 mg/l ± 2.0 mg/l	Condition 2[3] For large or coarse filters. 15 mg/l ± 3.0 mg/l
Initial contamination level for Main Reservoir and circuit (test filter system)	Less than 1% of the minimum specified in Table 3A or 3B, "Acceptable Cumulative Particle Count per Milliliter." Measure at the minimum particle size to be counted.	Less than 1% of the minimum specified in Table 3A or 3B, "Acceptable Cumulative Particle Count per Milliliter." Measure at the minimum particle size to be counted.
Initial contamination level for injection reservoir and circuit	Less than 1% of injection gravimetric level.	Less than 1% of injection gravimetric level.
Recommended particle counting sizes[4]	Minimum of five sizes selected to cover the presumed filter performance range from Beta = 2 to Beta =1000. Typical sizes are 5, 10, 20, 40, 80, 100 and 150 micron.	Minimum of five sizes selected to cover the presumed filter performance range from Beta = 2 to Beta =1000. Typical sizes are 5, 10, 20, 40, 80, 100 and 150 micron.
Sampling and counting method	Online automatic particle counting	Online automatic particle counting

1. This table lists two contamination concentration levels. Test Condition 1 may be used for small or high efficiency filters. Test Condition 2 may be used for large or coarse filters. Test Contaminant Concentration has a significant impact on reported efficiency, capacity and test duration. Concentrations should be selected such that test duration is at least 120 minutes. The test requester must specify which Test Condition to use.
2. When comparing test results between two filters, the base upstream gravimetric level should be the same.
3. To establish particle size distribution, especially for Coarse Sieved contamination, see 4.3.1.1 and 4.3.1.2 regarding preferred test contaminants and the procedures described therein for qualifying the particle size distribution. Also see the note following Table 3B.
4. Particle size counts where filter beta ratings high (Beta = 200 or greater) may be unobtainable for coarse filters.

TABLE 3A—ACCEPTABLE CUMULATIVE PARTICLE COUNTS PER 100 MILLILITERS FOR STEADY STATE MULTI-PASS OR PULSED FLOW EFFICIENCY TESTS, MEDIUM SIEVED GRADE (20 TO 140 MICRONS)

Particle Size (microns)	Test Condition 1 Min	Test Condition 1 Max	Test Condition 2 Min	Test Condition 2 Max
20	3000	6000	4500	9000
40	1000	2000	1500	3000
60	500	1000	750	1500
80	200	400	300	600
100	50	100	75	150
120	50	100	75	150
140	50	100	75	150

TABLE 3B: ACCEPTABLE CUMULATIVE PARTICLE COUNTS PER 100 MILLILITERS FOR PULSED FLOW EFFICIENCY TESTS, COARSE SIEVED GRADE (50/50 MIX; OF 150 TO 250 MICRONS, AND 250+ MICRONS)

Particle Size (microns)	Test Condition 1 Min	Test Condition 1 Max	Test Condition 2 Min	Test Condition 2 Max
140	1000	2500	1500	3750
160	600	1500	900	2250
180	300	750	450	1125
200	200	500	300	750
220	200	500	300	750
240	100	250	150	375
260	100	250	150	375
280	50	125	75	188
300	50	125	75	188

NOTE—High filter efficiency claims require a sufficient concentration of particles at the claimed micron size in the fluid to insure the filter media is adequately challenged, e.g., a claim of Beta = 100 at 200 microns requires a minimum concentration of 1000 particles at 200 microns.

4.4.6 TEST FLUID

Use petroleum based test fluid with properties as detailed in ISO 16889. MIL H-5606 G is one such fluid and is usually used. This fluid has worldwide availability and, because its manufacture is carefully controlled, its use assures greater reproducibility. It is also the fluid of choice in most other generally accepted filter test standards.

4.4.7 TEST CIRCUITS

The test circuits illustrated in Figures 1A and 2A are suitable for steady state contamination test and pressure drop tests. For more detailed information, refer to ISO 16889. Additional test circuits are described and illustrated in 4.4.8 of that standard and shown in figures referenced there.

4.4.7.1 Filter Test Circuit, Filter Efficiency, Capacity and Pressure Drop Test.

a. Use a reservoir, pump, fluid conditioning apparatus and instrumentation that are capable of accommodating the range of flows, pressures, and volumes required by the procedure, and is capable of meeting the validation requirements of 4.4.7.3.
b. Use a cleanup filter capable of providing an initial system contamination level as specified in Table 2, “Test Condition Values.”
c. Use a configuration that is relatively insensitive to the intended operative contaminant level.
d. Use a configuration that will not alter the test contaminant distribution over the anticipated test duration.
e. Use pressure taps in accordance with ISO 3968.
f. Use fluid sampling section upstream and downstream of the test filter in accordance with ISO 4021.
g. Outlet diffuser nozzle(s) shall be located below the fluid surface and all piping shall be designed to result in turbulent flow.
h. For “Suction Mode” circuits (see Figure 2A) the following additional requirements apply:
    1. The Main Reservoir must have a fluid circulation system consisting of a pump, piping and outlet diffuser of appropriate design to provide one to two complete reservoir fluid changes per minute.
    2. The upstream automatic particle counter shall be fed from a pressure tap in the re-circulation system.
    3. The test filter will be located in the Main Reservoir, below the surface of the fluid, and fixtured in the same orientation as found in the vehicle.

NOTE—Manual sampling, i.e., “bottle sampling,” is not suitable for particle counting and should be used for gravimetric analysis only. For bottle sampling, quarter-turn ball valves must be used. For particle counting devices, suitable sample connectors must be fitted at the filter inlet and outlet connections. These connectors must be in accordance with ISO 4021 “Hydraulic Fluid Power - Particulate Contamination Analysis; Extraction of Fluid Samples from Lines of Operating Systems.” These fittings are specially designed to permit sampling of fluid at reduced flow rates without collecting test contaminant themselves and thus affecting the particle concentration and distribution.

4.4.7.2 Contaminant Injection System (Filter Efficiency Tests only)

a. Use a reservoir, pump, fluid conditioning apparatus and instrumentation that are capable of accommodating the range of flows, pressures, and volumes required by the procedure, and is capable of meeting the validation requirements of 4.4.7.3.
b. Use a configuration that is relatively insensitive to the intended operative contaminant level.
c. Use a configuration that will not alter the test contaminant distribution over the anticipated test duration.
d. Fluid sampling section upstream and downstream of the test filter shall be in accordance with ISO 4021. See “NOTE” in 4.4.7.1.

4.4.7.3 Filter Test System Validation

For test stands operated as illustrated in Figure 1A “Intake Filter Test Circuit - Pressure Mode,” or Figure 2A “Intake Filter Test Circuit - Suction Mode”, test stand validations must be in accordance with ISO 16889. Regardless of test method, test stand validation must be verified no less than once per calendar quarter.

4.4.8 ADDITIONAL TEST CIRCUITS

4.4.8.1 Additional test circuits are illustrated in Figure 1B, “Pressure Mode, Pulsed Flow Efficiency Test”, and Figures 2B, “Suction Mode, Pulsed Flow Efficiency Tests”. The following requirements apply:

a. The requirements contained in 4.4.7.1 (A) through (H) including the capability of meeting the validation procedures 4.4.7.3.
b. The pulse control circuit (bypass circuit) must produce a time response such that the first time constant for the required flow amplitude defined on the Filter Application and Data Sheet (see Figure 6) is less than 200 millisec. See Figure 8, “Pulsed Flow Efficiency Test, Time/Pressure Profile.”
c. Equipment and circuit connections illustrated in Figure 1B are essentially identical to Figure 1A, “Steady State Multi-Pass Efficiency Test” except a bypass valve is added to achieve rapid acceleration and deceleration of flow through the test filter. The Main Reservoir pump capacity may need to be greater than that required for “Steady State Multi-Pass Tests.”
d. Equipment and circuit connections illustrated in Figure 2B are essentially identical to Figure 2A, “Suction Mode, Steady State Multi-Pass Test” except a bypass valve is added to achieve rapid acceleration and deceleration of flow through the test filter. The Main Reservoir pump capacity may need to be greater than that required for “Steady State Multi-Pass Tests.”

4.4.8.2 Extreme Cold Temperature Equipment

The equipment used for these tests is intended to establish flow and pressure drop relationship only. No contamination testing is intended to be completed with this equipment. See Figures 7A and 7B.

a. Use a reservoir, pump, (accumulator or cylinder rigged to compel flow through the filter) appropriate controls, fluid conditioning apparatus and instrumentation that are capable of accommodating the range of flows, pressures, and volumes required by the procedure.
b. Thermal enclosure and heat transfer equipment must not create localized cold or hot areas in excess of ±2 °C (±4 °F).
c. Flow measurement devices must be capable of discerning presence of undissolved air or be a mass flow meter. It must be intended for extreme temperature and fluid viscosity and able to be calibrated for use under these conditions. The flow meter must not be located between test filter and pressure gauge.
d. Test Fluid should be "Factory Fill" ATF with verification that water content and cleanliness meet factory specifications. Undissolved air must be absent at Standard Temperature and Pressure (STP).
e. If operated in "Suction Mode," see Figure 7A, an alternative to flow measurement may include measurement of cylinder displacement (movement) with appropriate signal conditioning and algorithms to indicate flow rate and total volume passed.
f. If operated in "Pressure Mode," see Figure 7B, test filter must be installed in a rigid leak free test fixture (sealed housing) and differential pressure must be measured.
g. If a test circuit illustrated in Figure 7B is used, the cold reservoir must be of sufficient size to provide a controlled rise in flow from zero to rated cold flow.
h. All instrumentation must be capable of operation at the temperature and fluid characteristics encountered under these tests, and such parameters defined in the equipment's ratings.

Filter Design/Application Data Sheet

Filter Part No.		Program:	
Filter Manufacturer		Description :	

Parameter	ES-SPEC/ SDS PARA. NO.	Sample Size	Acceptance Criteria		Reference			Latest Change Date/Initials
			Parameters	Reliability	Procedure	FMEA Para. No.	DVP&R	
Application								
Vehicle Line								
Transmission Models								
Engine (s)								
Factory Filled Fluid								
Ratings – Filter Assembly (Housing & Element)								
(See note 1) * Load Capacity – ISO 12103-1A 4								
(See note 1) * Load Capacity - Metallic Compound								
(See note 1) * Terminal Pressure Drop								
(See note 1) * Beta Rating								
(See note 1) * Media Migration								
(See note 2) * Flow – Clean Element– -18C @ .035 kPa dif								
(See note 2) * Flow–Clean Element– +100C @ .035 kPa dif								
(See note 1) * Pulsed Flow – min flow								
(See note 1) * Pulsed Flow – max flow								
(See note 1) * Pulsed Flow – Duration at min flow								
(See note 1) * Pulsed Flow – Duration at max flow								
(See note 1) * Pulsed Flow – time constant								
(See note 2) * Max Rated Inlet Temperature								
(See note 2) * Max Inlet Over Temperature								
Ratings: Valve (if equipped)								
DrainBack								
Bypass Valve								
*Cracking Pressure								
* Max kPa diff @ flow rate								
Max Rated Flow								
Environmental/Mounting/Service								
Service Interval								
Hydraulic Fatigue								
* Shell								
*Seal - Fretting								
*Seal – Creep								
* Crimp								
Proof Pressure								
Crush – peripheral								
Crush – Normal								
High Temp Endurance								

Notes:
1. Performance test using MIL 5606 or equivalent
2. Performance test with Factory Fill Fluid

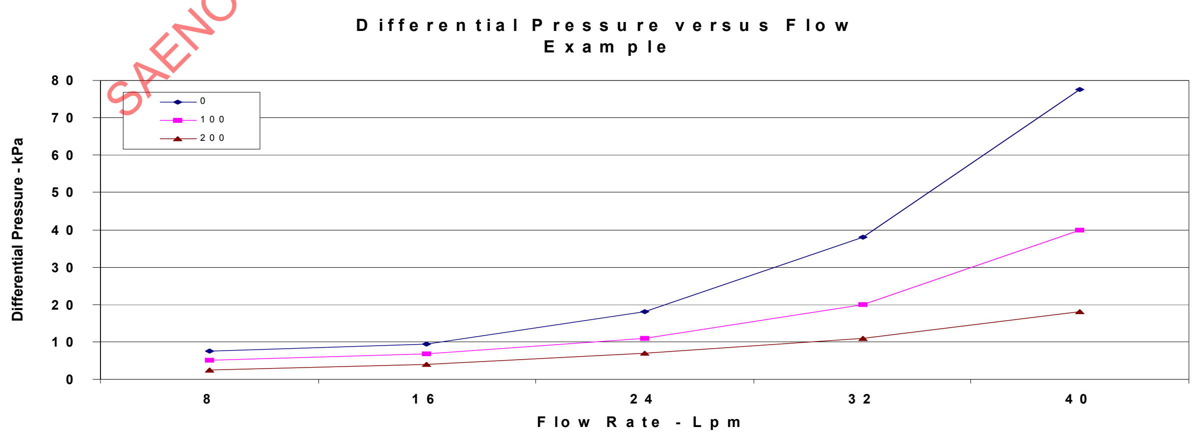

FIGURE 6—FILTER DESIGN/APPLICATION DATA SHEET

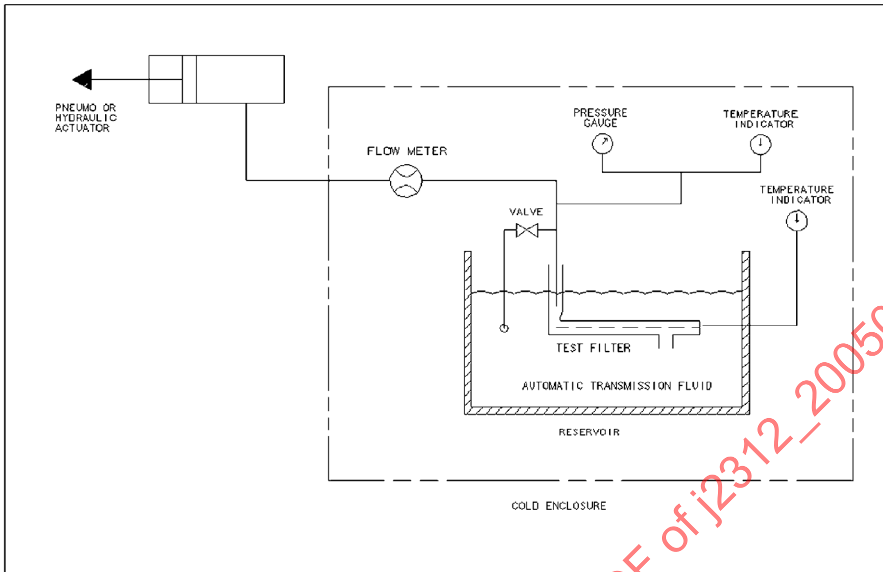

FIGURE 7A—EXTREME COLD TEMPERATURE TEST CIRCUIT: SUCTION MODE

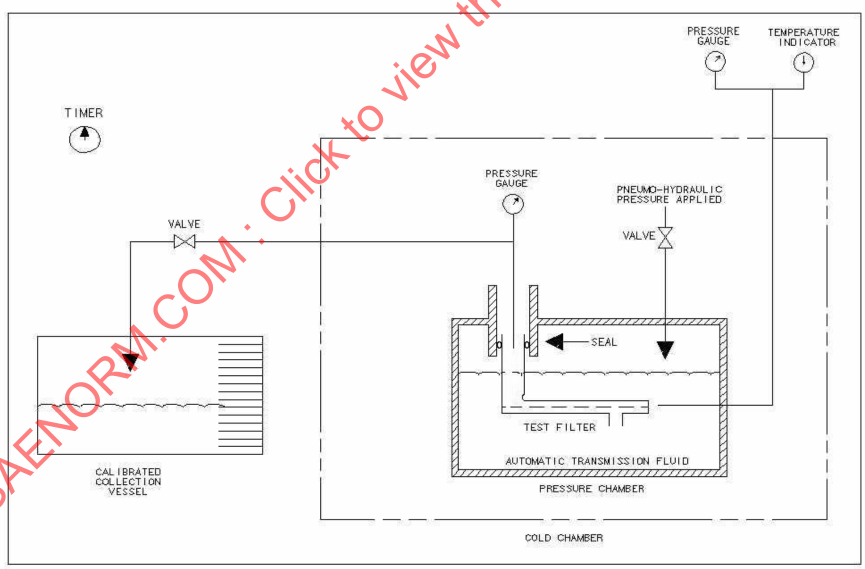

FIGURE 7B—EXTREME COLD TEMPERATURE TEST CIRCUIT: PRESSURE MODE

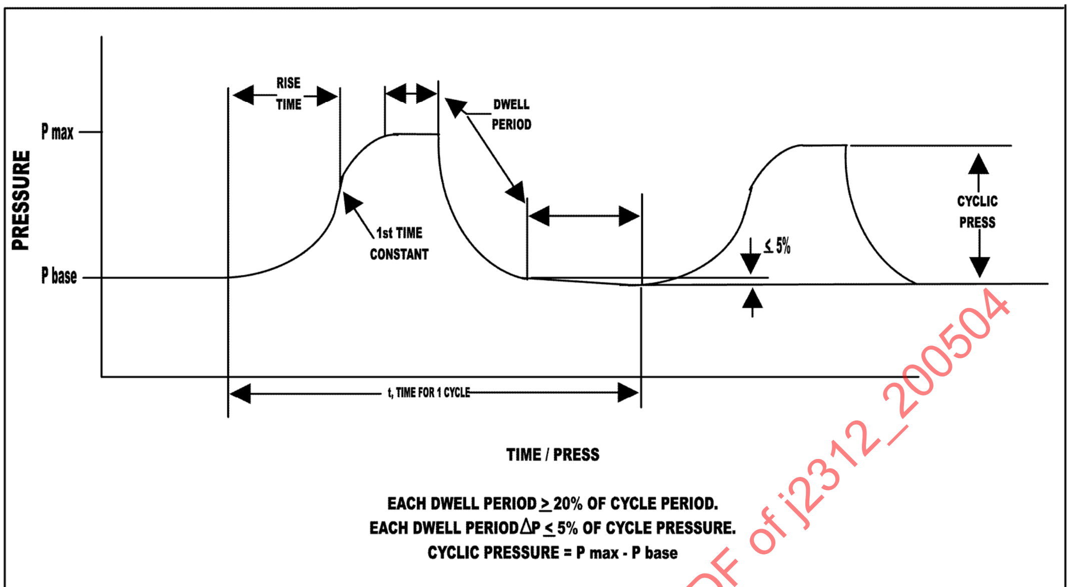

FIGURE 8A—PULSED FLOW EFFICIENCY TEST: TYPICAL PULSED FLOW PROFILE

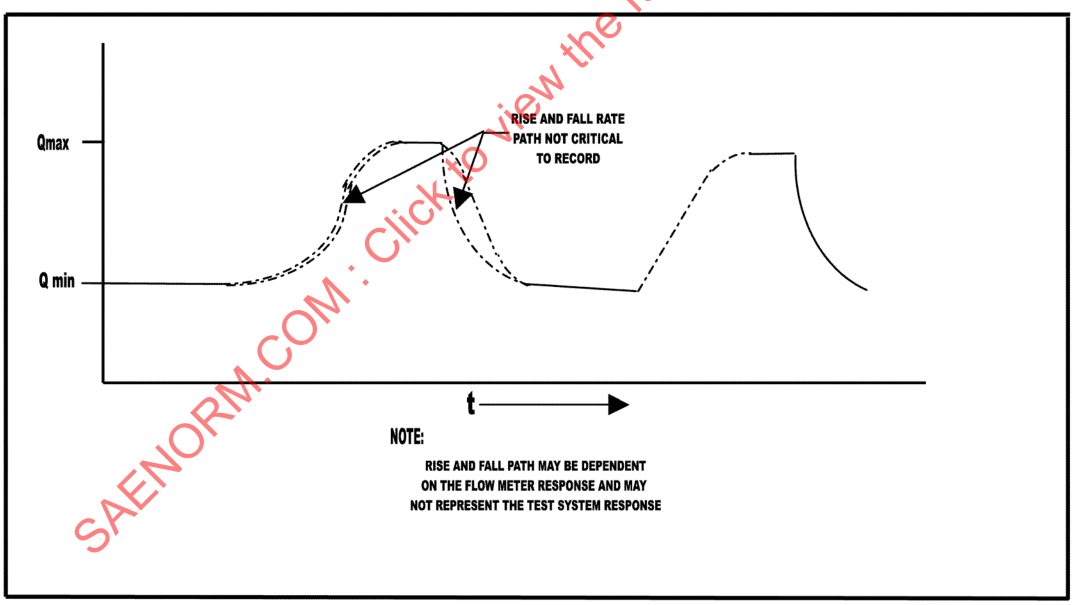

FIGURE 8B—PULSED FLOW EFFICIENCY TEST: TYPICAL PULSED FLOW PROFILE RISE AND FALL RATE GUIDANCE

4.5 Equipment for Gravimetric Analysis

(For reference, see ISO 4405)

4.5.1 Filter Analysis Patch (Analytical Membrane Filters), white, plain, 47 mm OD, 0.8-micron and 5-micron pore sizes.

4.5.2 Filter Holder, 47mm of borosilicate glass or stainless steel funnel and funnel base, plus clamps (2), Aspiration Flask, and stainless steel trays, and rubber stoppers.

4.5.3 Analytical Balance accurate to 0.0001 g.

4.5.4 Petri Dishes, 60mm ID

4.5.5 Non-circulatory Air Oven for 100 °C

4.5.6 Forceps, flat bladed (3)

4.5.7 Wipes, lint free

4.5.8 Squirt Bottles or pressurized spray tank with gun

4.5.9 Washing and Storage Bottles

4.5.10 Desiccator

4.5.11 Gloves, particulate free impermeable

4.5.12 Vacuum System capable of achieving 380 mm Hg vacuum.

4.5.13 Solvent, filtered to 1 micron - petroleum based with flash point at 60 °C or higher is preferred, e.g., Stoddard Solvent P-D-680 Type IIA, or "Exxsol," Exxon Corp., (naphtha D-60).

4.6 Data Acquisition System

The data acquisition system for filter tests described in this document should be capable of monitoring and recording all input variables. This includes but is not limited to signals relating to time, pressures, particle counts, temperatures, flow rates and miscellaneous electrical signals which translate into specific parameters such as liquid level. The system should be capable of monitoring and recording data from both normal system operation mode and from calibration or validation mode. Data acquisition should have the capability of no less than 10,000 counts per second for any single channel

5. Test Procedures

5.1 Filtration Efficiency

Applicable to Filter Assembly or Media Test fixture.

5.1.1 STEADY-STATE MULTI-PASS

5.1.1.1 Test Preparation

Use a data sheet similar to that illustrated on Figure 4 "Filter Assembly Test Report – Steady State Multi-Pass Test." Complete all pertinent blocks and record all test results on this form.